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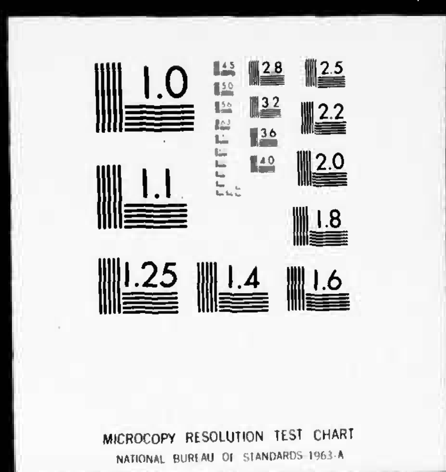

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GENERAL AVIATION DYNAMICS

AN EXTENSION OF THE COST IMPACT STUDY TO INCLUDE DYNAMIC INTERACTIONS IN THE FORECASTING OF GENERAL AVIATION ACTIVITY

VOLUME I. EXECUTIVE SUMMARY

APRIL 1977

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Office of Aviation Policy
Aviation Forecast Branch
Washington, D.C. 20591

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16. Abstract

This report, in four volumes, presents the General Aviation Dynamics (GAD) model which was developed for the Federal Aviation Administration by Battelle's Columbus Laboratories. The GAD model is a dynamic simulation model of the general aviation (GA) system and can be used to forecast GA activity, evaluate alternative policy actions, or perform sensitivity analyses. It has three major sectors, depicting the most important state variables in the model; pilot supply, aircraft utilization, and aircraft demand.

Essentially, the GAD model consists of a set of nonlinear, simultaneous, first order difference equations which explicitly describe the decision policies followed by users of general aviation. The model is designed to be implemented through an interactive computer dialogue feature that guides the analyst through a series of procedures and analytical options.

The volumes included in this report are:

Volume I - Executive Summary
Volume II - Research Methodology
Volume III - Planning Guide
Volume IV - Data Base

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FINAL REPORT

on

GENERAL AVIATION DYNAMICS
AN EXTENSION OF THE COST IMPACT STUDY TO INCLUDE DYNAMIC INTERACTIONS IN THE FORECASTING OF GENERAL AVIATION ACTIVITY

VOLUME 1: EXECUTIVE SUMMARY

to

FEDERAL AVIATION ADMINISTRATION
OFFICE OF AVIATION POLICY

from

BATTELLE
Columbus Laboratories

by

M. A. Duffy, G. L. Eiden, C. W. Hamilton, and V. J. Drago

December 31, 1976

INTRODUCTION

Credible aviation forecasts are essential to the Federal Aviation Administration for two purposes: short term forecasts provide support for the budgetary process, while long term forecasts establish the basis for planning, research, and development necessary to meet the needs of the national aviation system. Of primary importance is an accurate assessment of the expected future growth of general aviation (GA). These forecasts, already complex, become extremely difficult when evaluating possible alternative federal policies.

Despite the complex nature of the general aviation system and the rapid response time desired when evaluating future policies, computer simulation models have received little or no attention from aviation analysts. Furthermore, although various aspects of general aviation have been investigated in the past, there has been little attempt to place these individual studies and their results within the framework of an entire feedback model. The purpose of this

research program is to develop a dynamic simulation model of the general aviation system, which recognizes the important interrelationships between all sectors of general aviation.

The resultant model quantifies the different behavioral characteristics of 29 distinct user category/aircraft type subsegments within general aviation. It can be used to evaluate those policies which can be translated into fixed costs, variable costs, or level of service for competitive air travel at the national level. However, it cannot perform regional analyses, nor evaluate restrictions imposed at selected airports.

Although the development of the model has relied on as little as four years data, the results should serve as a starting point for continuing research and new data implementation.

Background

Under two earlier contracts (Contract Nos. DOT-FA72-WA-3118 and DOT-FA74-W-3485) Battelle developed the methodology, data base, and results needed to aid FAA planners in quantitatively assessing the cost impact of proposed regulatory changes. In both studies, cost-impact relationships were based upon regression analyses using historical data obtained during a period of relatively steady national economic growth.

The recent nationwide fuel crisis revealed several inadequacies in these methods. In particular, important effects not previously accounted for are the causal interactions that take place between various sectors of the general aviation system. Also, for certain subsegments, the availability of competitive modes of travel can be important. In contrast to availability, the relative costs of competitive modes of travel, which were expected to be important in determining general aviation aircraft utilization, were not significant within the range of available data.

One observation that was evident during previous studies, is that different user categories within general aviation respond differently to various stimuli. In fact, major differences can even be found for different aircraft types within the same user category. Given a paucity of time series data,

determining the different behavioral responses raises a difficult estimation problem. In order to obtain statistical significance, it is necessary to pool cross-sectional observations. An alternate approach is to estimate distinct behavioral responses with lesser precision based on a short time series. Both approaches were included in developing the current model.

Seven distinct user categories and seven different aircraft types were chosen for detailed analyses. Of the 49 possible subsegments, only 29 have had a significant amount of activity. This matrix of 29 subsegments is illustrated in Table 1-1. Complete definitions of each user category and each aircraft type are given in Volume II.

TABLE 1-1. SIGNIFICANT USER CATEGORY/AIRCRAFT TYPE SUBSEGMENTS OF GENERAL AVIATION*

User Category I \ Aircraft Type J	1	2	3	4	5	6	7
1		X		X	X		X
2		X				X	
3		X		X	X		X
4	X			X	X		X
5		X		X	X		X
6		X					
7		X					

User Categories

1. Business
2. Corporate
3. Personal
4. Aerial
5. Instruct.
6. Air Taxi
7. Other

Aircraft Type

1. Single-Eng. Piston Nonaerial
2. Single-Eng. Piston Aerial
3. Multi-Engine Piston
4. Turboprop
5. Turbojet
6. Piston Engine Helcptr.
7. Turbine Engine Helcptr.

*X denotes insignificant activity

During the previous Cost Impact studies, major cost centers were defined for both the variable cost of aircraft operation and the fixed cost of aircraft ownership. Individual cost centers are designated in Table 1-2.

TABLE 1-2. COST CENTERS FOR GENERAL AVIATION AIRCRAFT

Variable Costs ($/hour)

- Fuel and Oil
- Airframe and Avionics Maintenance and Overhaul
- Engine Maintenance and Overhaul

Fixed Costs ($/year)

- Annualized Investment
- Hull Insurance
- Liability and Medical Insurances
- Hangar, Storage and Tie Down
- Federal Registration Fee and Weight Tax
- Miscellaneous

Objectives

Forecasts produced by trend extrapolation and aggregate analyses may be adequate for some applications, but acceptable policy evaluations, which introduce heretofore unknown disturbances, depend on a better understanding of the system. In particular, the causal interactions between various sectors of general aviation are most important when assessing total system response to exogenous factors.

The objectives of this research program were to

(1) Develop a dynamic simulation model of the general aviation system which could be used for forecasting and policy evaluation.

(2) Computerize the model for quick efficient use by FAA personnel.

The lack of an adequate data base has been a persistent problem in analyzing the behavior of general aviation. Within the present study, primary emphasis is placed upon the identification of the logical structure creating the diverse activities within GA. Data limitations are evident when attempting to quantify some behavioral expressions, but it is hoped that these discrepancies will be satisfied as more current data become available.

Methodology

A method is needed which;

(1) Focuses on general aviation activity at the lowest possible level; that is, by individual user category/ aircraft type subsegments.

(2) Recognizes the important causal interactions between pilots, aircraft, and annual hours flown.

(3) Has the ability to assess various policy alternatives quickly.

(4) Can be easily modified as future forecasting requirements are identified.

The system dynamics approach for continuous simulation was chosen as the basis for model construction. Originally developed at M.I.T., system dynamics has been in use at Battelle for over a decade. Recognizing the versatility of this modeling technique, a computer-based dynamic simulation and modeling system, NUCLEUS, has evolved as a result of numerous multidisciplinary research projects at Battelle. Through NUCLEUS, the General Aviation Dynamics model is available on-line and is easily accessed through a conversational dialogue feature.

During model development, the main consideration is identifying the important system variables and how they interact; not only with exogenous factors, but among themselves. Preservation of these dynamic interactions within general aviation is a significant difference between this study and earlier statistical analyses. This is not to say that econometric regression techniques were not used in quantifying certain functional relationships in this model. However, instead of applying regression analysis directly to the absolute level of state variables

(e.g., active aircraft, hours flown, etc.), it was the rates of flow into and out of these levels that were estimated. These first difference equations represent the actions taking place within the general aviation system - aircraft being continuously activated and deactivated, airman certificates being issued, aircraft being destroyed, etc. It is the net accumulation of these rates of flow that determines the condition of the system at any point in time.

In general, there are two ways to use model results or simulations - individually as projections and in pairs as sensitivity measures. Use of the model simply to make projections is precarious. Many potential users will not understand how the projections were derived and will expect unreasonable accuracy. The model is better used by employing extensive sensitivity analysis to evaluate a range of policies under a range of exogenous conditions. This process will identify the principal areas of model uncertainty and those portions of the model that deserve the greatest additional research.

AN OVERVIEW OF THE MODEL

Activity within the general aviation system is the result of causal interactions between three major sectors: pilot supply, aircraft utilization, and aircraft demand. Failure to recognize the interrelationships between these sectors, is equivalent to assuming that they are independent of each other. A flow diagram of the entire General Aviation Dynamics (GAD) model is illustrated on Figure 1-1. By the nature of its construction, the model asserts that the relationships chosen for inclusion are important, that any omitted relationships are less important, and that "real world" interactions can be represented usefully as described in the details of the model.

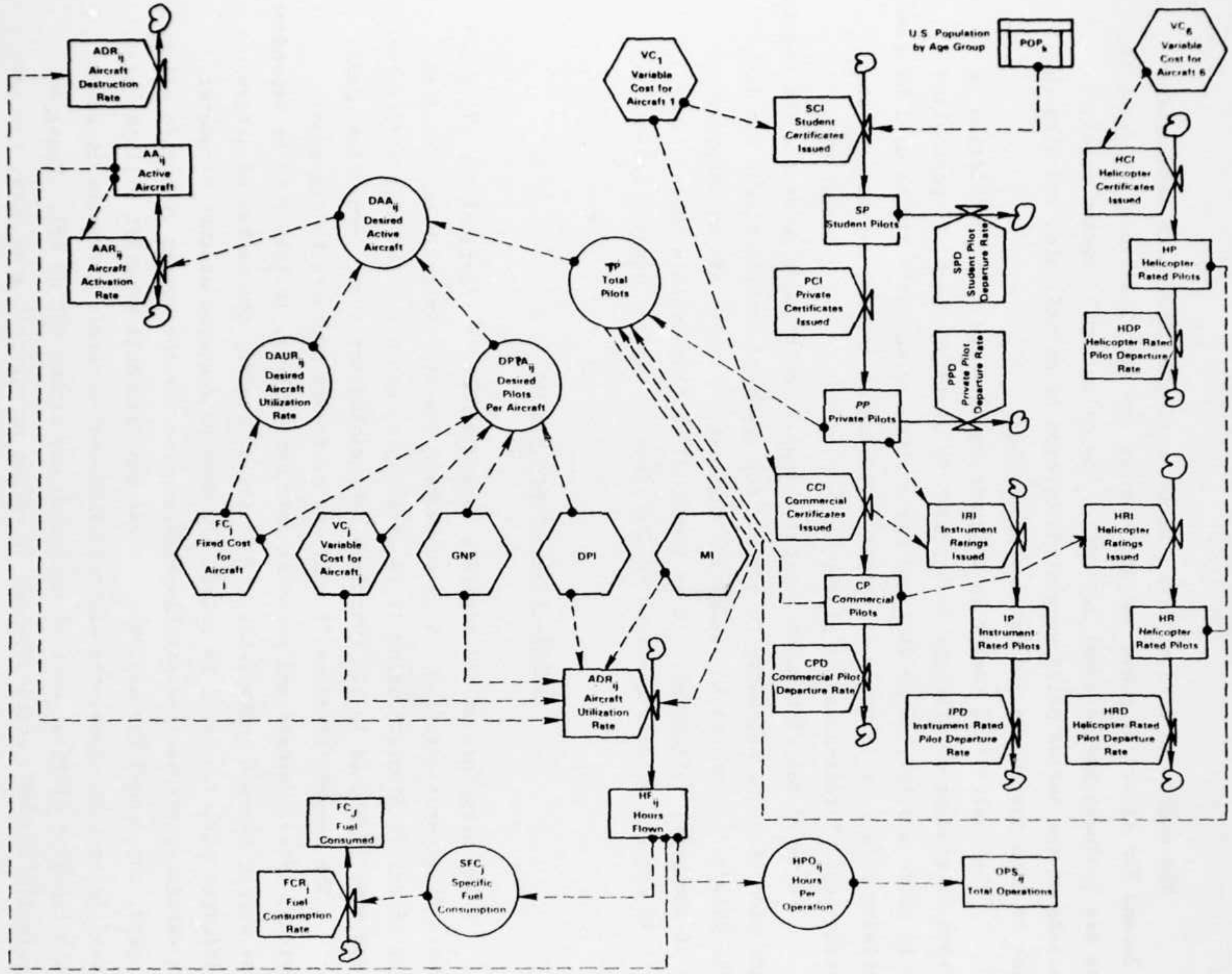

FIGURE 1-1. GENERAL AVIATION DYNAMICS FLOW DIAGRAM

The Pilot Supply Sector

The number of active airmen is an important element in determining the demand for aircraft, owned and operated by the same individual. Typically, these are business and personal aircraft. The pilot supply sector develops forecasts of the active pilot population by type of certificate, and also the number of both instrument and helicopter ratings.

The controlling factor in determining ultimate pilot population is the rate of student certificate issuances. By dividing the U. S. population over 16 years old into three distinct age groups, recent data can be used to show a definite relationship between student certificates issued, population, and relative cost of instructional flying.

A valid description of the pilot supply sector must recognize the required progression of steps necessary to qualify for advanced certificates. The inherent delays encountered in satisfying these requirements are an important part of the model definition. It is these delays that explain the continued growth in numbers of active pilots during times of reduced student issuances.

The Aircraft Demand Sector

The structure of the aircraft demand sector is identical for all subsegments of general aviation. Each subsegment has its own goal for a desired number of active aircraft which it is striving to achieve. The main difference between subsegments is in the functional expression for their respective goals.

The demand for aircraft that are owned and operated by the same individual (viz. business and personal user categories), is likely to be dependent on the supply of such individuals. This is, of course, the number of active certificated pilots. So it is relatively easy to conceive another parameter which describes the desired-pilots-per-aircraft. As the number of active pilots increases, the demand for active (business and personal) aircraft will increase. However, in certain cases, the desired-pilots-per-aircraft parameter is shown to be a function of total cost of operation and either GNP or DPI. Thus, as the relative economic attractiveness of owning an aircraft goes down, the same number of pilots will demand fewer aircraft.

The demand for aircraft that are used in providing a service (viz. aerial application, instructional, air taxi and rental) is dependent on the extent to which these aircraft are presently being used. Should the average annual utilization rate of a particular aircraft type within one of these user categories surpass some threshold, then there will be a need for additional aircraft to satisfy what may be an excess demand. The goal for desired number of active aircraft is related to the ratio of desired aircraft utilization rate and actual aircraft utilization rate. Except for aerial applications, the desired aircraft utilization rates within other subsegments have been insensitive to changes in economic variables.

Demand for corporate aircraft is based on a desired number of active aircraft which is directly related to general economic conditions. Intuitively, this functional dependence is appealing. For, should economic growth be stagnated and real GNP remain constant, the desired number of corporate aircraft will remain constant. Ultimately, the demand for additional corporate aircraft would represent only replacement of destroyed aircraft. However, if the economy continues to grow, an ever increasing number of active corporate aircraft will be desired.

The Aircraft Utilization Sector

Several different behavioral subsegments are evident within the aircraft utilizati - sector. First is the owner-operator situation, characterized by the business and personal use categories. Here an aircraft is purchased and operated by the same individual. The average annual utilization rate for these aircraft have been varying about a nominal value. Thus, total annual utilization within each subsegment is obtained by taking the product of active aircraft and average annual utilization rate.

Demand for aerial application, instructional, and air taxi flying represents an aggregate demand for a general aviation service. The total annual hours demanded are distributed among the available aircraft to determine a derived annual utilization rate. These derived utilization rates are used in determining the demand for additional aircraft in these categories.

Behavior of the single and multi-engine piston aircraft owners within the "other" use category, which are predominantly rental operations, is similar to the total hours flown approach. The remaining segments of the "other" user category are based on average utilization rates.

Different user category/aircraft type subsegments respond to different stimuli. Utilization, either average rate or total hours, has shown a significant correlation with variable cost of operation in only a few of the 29 subsegments. Some subsegments have indicated utilizations dependent on GNP, DPI, or the level of commercial air activity. However, the form of these dependencies is, in some cases, opposite the a priori expectation.

The forecasted level of annual hours flown is used to determine the corresponding level of operations within each subsegment. Operations are distinguished by local-itinerant, towered-non-towered, and IFR-VFR. Annual hours flown is also used in calculating the amount of both piston and jet fuel consumed.

The Dynamics of Aircraft Demand

The structure of the aircraft demand sector is identical for all subsegments of general aviation. However, because of the various uses of general aviation aircraft, the desired stock of active aircraft is determined differently for different users. At any point in time, each subsegment has a certain number of active aircraft and a desired number of active aircraft which it is striving to achieve. This desired stock can be greater than, less than, or equal to the actual number of active aircraft, depending upon other conditions within the system. Of special interest in explaining fluctuations in aircraft activation is the role of pilot population, average aircraft utilization rates, and exogenous economic parameters.

The demand for aircraft is a derived demand, the primary demand being for transport services provided by the aircraft. This derived demand is demand for a stock (or goal) of aircraft, not for the flow of aircraft activations. The goal, DAA, desired-active-aircraft, can be a complex function of the number

of pilots, the average aircraft utilization rate last year, fixed costs, variable costs, and exogenous inputs for GNP or DPI. For any particular subsegment, if the stock of aircraft desired is greater than the current number of active aircraft within that subsegment, then additional aircraft will be activated; otherwise, aircraft would be deactivated. Thus, the dynamics within the general aviation system are the result of continuous causal interactions between the pilot supply sector, the aircraft utilization sector, and the aircraft demand sector.

To illustrate, consider the demand for business single-engine piston aircraft, displayed in Figure 1-2. DPPA, desired-pilots-per-aircraft, relates the demand for business aircraft to the number of active pilots.

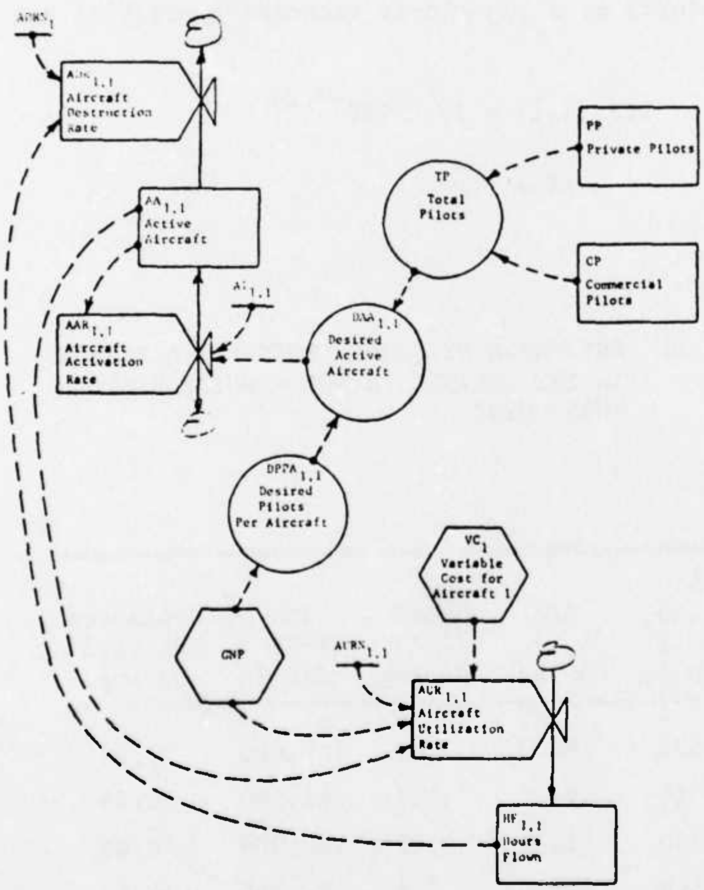

FIGURE 1-2. BUSINESS/SINGLE-ENGINE PISTON EXAMPLE

The goal for active aircraft DAA, desired-active-aircraft, is simply

$$DAA(I,J) = TP/DPPA(I,J)$$

where TP is total pilots and is equal to the sum of private plus commercial pilots when J identifies fixed wing aircraft.

Values for DPPA(1,1) over time can be determined from the data presented in Table 1-3. DPPA is not likely to be a constant but should be reflective of general economic conditions as well as the relative cost of aircraft ownership. Figure 1-3 indicates the variation of DPPA(1,1) with percentage changes in GNP measured in constant 1972 dollars and indexed to the 1972 value of GNP. Results of a log-linear regression analysis are

$$DPPA(1,1) = 20.0\ GNP^{-3.23}$$

$$R^2 = 0.97$$

TABLE 1-3. ESTIMATED DESIRED-PILOTS-PER-AIRCRAFT IN THE BUSINESS/SINGLE-ENGINE PISTON SUBSEGMENT

Year	AA (1,1) as of Jan 1	ADR (1,1) During	AAR (1,1) During	TP= PP+CP Jan 1	Estimated DPPA(1,1) During
1971	20,522	94	-344	467,000	23.54
1972	20,084	93	1549	481,000	20.75
1973	21,540	114	3943	490,000	16.65
1974	25,369	125	768	481,365	17.89
1975	26,012			498,273	

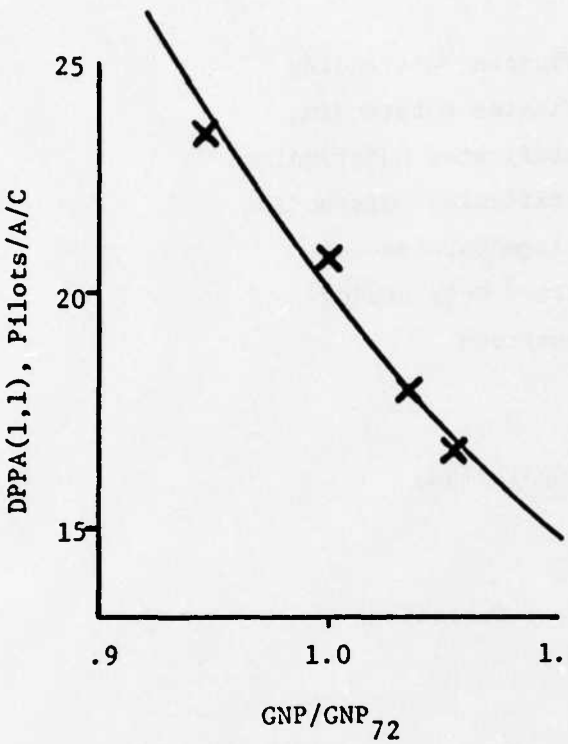

FIGURE 1-3. DESIRED-PILOTS-PER-AIRCRAFT AS A FUNCTION OF GNP

Similar analyses were performed for components of each rate equation within the GAD model.

Model Output

The General Aviation Dynamics model can be used to forecast active aircraft, annual hours flown, and total operations for each of the 29 user category/aircraft type subsegments identified in Table 1-1. Although activity is disaggregated to this level, it is not yet possible to perform regional analyses; only the level of aggregate U. S. activity can be projected.

Other forecasts that can be obtained are,

- Active Airmen
  - Student Certificates Outstanding
  - Private Certificates Outstanding
  - Commercial Certificates Outstanding
  - Helicopter Certificates Outstanding
  - Instrument Ratings Outstanding
  - Helicopter Ratings Outstanding
- Annual Fuel Consumption
  - Aviation Gas
  - Jet Fuel
- Towered Airport Operations
  - Itinerant
  - Local
- Non-Towered Airport Operations
  - Itinerant
  - Local
- Total Operations
  - IFR
  - VFR
- GA Contributions to the Federal Trust Fund

Relative comparisons can be made between the model forecasts from any two simulations. During a sensitivity analysis, absolute forecasts for each simulation are available, and also percent deviations between the two cases. These results can be displayed over time either graphically or in tabular format.

Operations

Annual hours flown are forecast by individual user category/aircraft type subsegment. By linking operations directly to hours flown within each subsegment, the continuously changing mix of operations, as dictated by the level of activity within each subsegment, is preserved. A basic assumption is that

the average time per trip (or time per operation) for each subsegment will remain constant throughout the forecast period. Table 1-4 contains the average time per operation within each subsegment. These values are based on the best currently available data and are consistent with estimates of 1973 operations. Similar tables were constructed which indicate the relative percentages of local and itinerant, tower and non-tower, and IFR and VFR operations.

TABLE 1-4. CY 1973 HOURS/OPERATION

User Category I	Aircraft Type J 1	2	3	4	5	6	
1	.18		.14			.38	
2	.25		.59	.20	.25	.75	
3	.2		.08			.05	
4		2.12	.15			1.86	
5	.16		.07			.34	
6	.26		.38	1.05	.48	8.88	
7	.76		.35	.08	.02	.99	

User Categories

1. Business
2. Corporate
3. Personal
4. Aerial
5. Instruct.
6. Air Taxi
7. Other

Aircraft Type

1. Single-Eng. Piston Nonaerial
2. Single-Eng. Piston Aerial
3. Multi-Engine Piston
4. Turboprop
5. Turbojet
6. All Helicopters

Fuel Consumption

Annual hours flown by aircraft type are used to estimate annual consumption of both aviation gas and jet fuel. Fuel consumption rates at 75 percent power were assumed in order to be consistent with the variable cost calculations.

SIMULATION OF THE MODEL

Baseline Forecast

The foundation for planning and policy evaluation by the FAA must be a baseline forecast of uninhibited general aviation activity. Data required for this baseline forecast are entirely self-contained within the model. GNP, DPI, and the current dollar deflator are derived from the Wharton national economy forecasts. Estimates of revenue aircraft departures, variable costs, and fixed costs are representative of current FAA expectations. Values for each of these parameters are included through CY 1984.

Figure 1-4 illustrates the expected growth in numbers of active general aviation aircraft and annual hours flown.

Evaluation of the Ullman Bill

HR 6860, the revised Ullman Bill, is of primary interest to the general aviation community because of its proposal to impose a conservation tax on gasoline. Assuming the bill would become effective on January 1, 1977, the GAD model indicates a 23-cents-per-gallon (the maximum possible) conservation tax would be instituted. The resultant increase in variable operating costs is expected to decrease general aviation activity as shown in Figure 1-5. However, general aviation contributions to the Federal Trust Fund would increase to $279 million during 1977 (Table 1-5) as opposed to the $60 million expected in the baseline forecast.

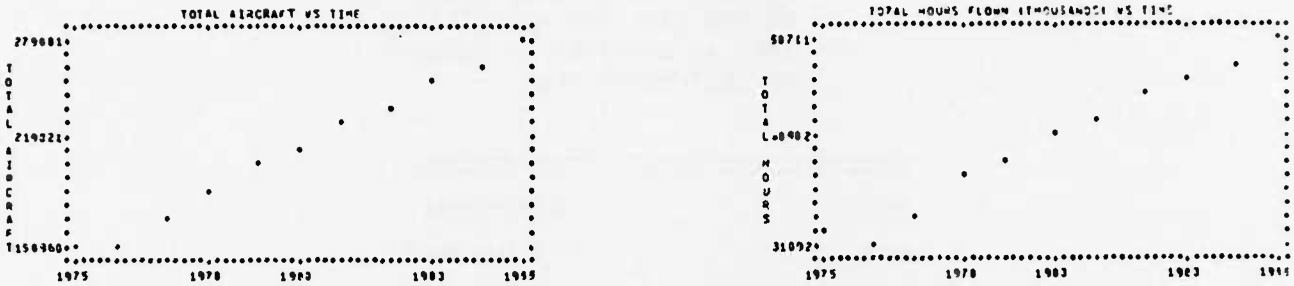

FIGURE 1-4. BASELINE GENERAL AVIATION ACTIVITY FORECAST

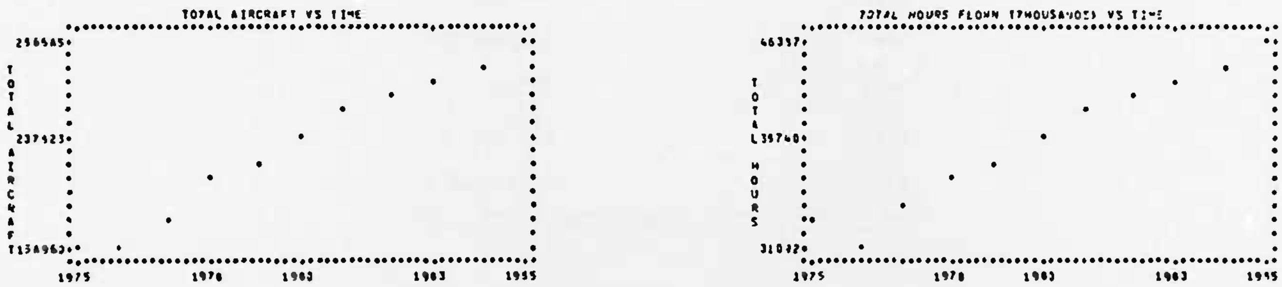

FIGURE 1-5. EXPECTED GENERAL AVIATION ACTIVITY UNDER THE ULLMAN BILL

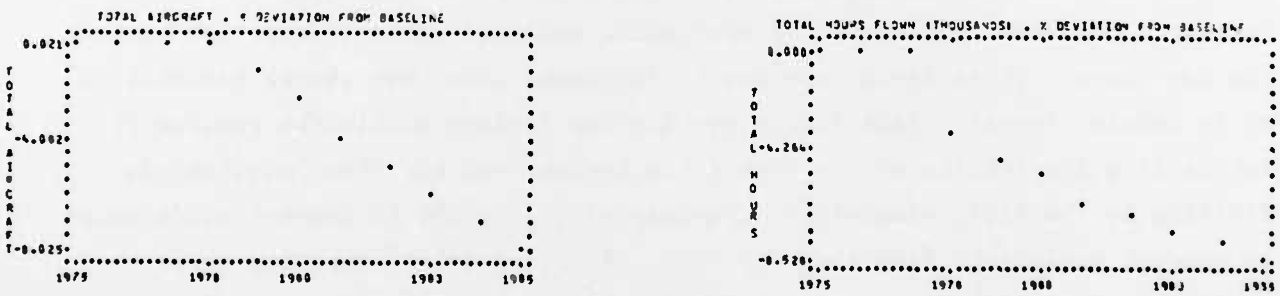

FIGURE 1-6. BASELINE/ULLMAN BILL COMPARISON

TABLE 1-5. FEDERAL TAX REVENUE UNDER THE ULLMAN BILL DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1976	$ 48,261,497
1977	54,555,921
1978	278,807,635
1979	300,291,725
1980	323,703,613
1981	349,082,650
1982	373,988,338
1983	397,021,476
1984	421,258,667
1985	456,818,116

Sensitivity Analysis

Relative comparisons can be made between the model forecasts from any two simulations. In particular, during a sensitivity analysis, absolute forecasts for each simulation are available, and also percent deviation between the two cases. These deviations can be displayed over time either graphically or in tabular format. Sensitivity results are derived within the program by subtracting the results of the second simulation from the first simulation, dividing by the first simulation, and multiplying by 100 to convert differences to percent deviations from the base case. By continually computing these deviations over time, the nonlinearity in system response is preserved.

Figure 1-6 illustrates relative comparisons between the two previous simulations.

IMPLICATIONS FOR FUTURE RESEARCH

A comparison of two different simulations has been presented. Volume II discusses some other types of policy evaluations. However, these are not the only possible uses of the model. Numerous applications are anticipated in answering questions, concerning the future of general aviation, from both the private and public sectors.

Ever since publication of the Cost Allocation Study, it has been desirable to have a method of assessing the impact of increased user charges on general aviation activity. Several research programs have been conducted in this area, including two previous studies by Battelle. At best, the results are tenuous because of the failure to recognize important causal relationships within the general aviation structure. By identifying these important structural aspects, the General Aviation Dynamics Model is capable of assessing the impact of increased fixed or variable costs, imposition of landing fees, and pilot regulatory actions. The model response, to user charges which increase costs substantially beyond those already experienced, should be carefully examined. As new data become available which can aid in extending the region of validity, they should be used to update statistical relationships within the model.

The demand for general aviation aircraft is of obvious importance to manufacturers and suppliers of general aviation equipment. Anticipated demand is also extremely important to the financial institutions which provide the funds required to purchase new aircraft. In fact, FAA forecasts are often used in deciding how much money to allocate for future aircraft financing needs. This is an example of the forecast being used to create conditions that were indeed forecast. Inclusion of such internal behavior is a simple matter within the structure of the GAD model.

At the very least, provisions should be made for updating the quantitative relationships within the model as new data become available. Additional research efforts could concentrate on adapting the model for regional analysis or expanding its coverage to the entire national aviation system. In applying the model to problems other than those for which it was designed, it may be necessary to introduce modifications, append additional sectors, and elaborate some sectors already in the model. The basic approach has been demonstrated; future applications are numerous.

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